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NATIONAL DEFENSE RESEARCH COMMITTEE

of

OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

WAR METALLURGY DIVISION

Progress Report

on

EXAMINATION OF ENEMY MATERIEL: METALLURGICAL EXAMINATION OF A 98-K MAUSER RIFLE OF 1941 (OD-113)

by

H. W. GILLETT, A. S. HENDERSON, L. H. GRENELL,
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BATTELLE MEMORIAL INSTITUTE

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November 12, 1943

To: Dr. James B. Conant, Chairman
National Defense Research Committee of the
Office of Scientific Research and Development

From: War Metallurgy Division (Div. 18), NDRC

Subject: Progress Report on "Examination of Enemy Materiel:
Metallurgical Examination of a 98-K Mauser Rifle of 1941"
(OD-113)

The attached progress report submitted by H. M. Gillett, Technical Representative on NDRC Research Project NRC-32, has been approved by representatives of the War Metallurgy Committee in charge of the work.

This report covers an examination of a single German Mauser rifle for details of fabrication, treatment, type of material, and workmanship.

I recommend acceptance as a satisfactory progress report under Contract OEMsr-721 with Battelle Memorial Institute.

Respectfully submitted,

Louis Jordan,
Technical Aide to the Chief
War Metallurgy Division, NDRC

Enclosure

PREFACE

This report is pertinent to the problems designated by the War Department Liaison Officer with NDRC as OD-113, and to the project designated by the War Metallurgy Division as NDRC Research Project MRC-32.

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PROGRESS REPORT No. 21

on

NDRC RESEARCH PROJECT NRC-32, OEMsr-722

EXAMINATION OF ENEMY MATERIEL

Metallurgical Examination of a 98-K Mauser Rifle of 1941

October 11, 1943

From:

BATTELLE MEMORIAL INSTITUTE

Report Prepared by:

L. H. Grenell
A. S. Henderson
J. G. Dunleavy
A. B. Westerman
J. R. Cady
Research Engineers

H. W. Gillett
Official Investigator

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ABSTRACT

Each of fifty-three parts was examined for details of fabrication, treatment, type of raw material, and workmanship. The plywood stock proved to be the most interesting change in this model of the Mauser rifle.

FOREWORD

A single German Mauser rifle, Model 98, Serial No. 4513, probably manufactured in 1941, was received from Aberdeen Proving Ground for metallurgical examination. The gun was complete except for the leather sling. All of the parts were in good condition, and the gun appeared to be in working order. Apparently, it had been in use for a moderate period of time before capture. The following markings were stamped on the gun barrel and the breech:

MOD. 98

41
4513

SUMMARY

The metal parts of this model of the Mauser rifle were, with few exceptions, made from plain carbon steel. Representative parts that were analyzed indicated that the basic open-hearth furnace was the source of most of the steel. The residual elements shown in these analyses indicated that scrap metal formed a considerable part of the charge. Only one part of eight heat-treated parts contained sufficient aluminum to control the grain size of the steel during the heat-treating operation. No instance was found of the use of high-sulphur screw stock, although many of the parts required extensive machining operations. With the exception of the usual blue-oxide gun-metal finish on a number of parts, there was no provision for prevention of corrosion.

A breakdown of the rifle parts as to the method of fabrication showed that 29 pieces were machined from bar stock, 6 were forged and machined, 10 parts (principally small springs and pins) were made from wire, 4 parts were stamped from sheet metal, and 2 parts were made from tubing. In machining the parts from bar stock, there were several instances of failure to orient the pieces with the flow lines of the steel in the most favorable direction.

Examination of the principal parts of the Mauser rifle for heat treatment showed that 17 parts were carburized, quenched, and tempered; 16 parts were quenched and tempered; and 7 parts were untreated. Twelve other parts (principally small springs and pins) were not examined. A number of the heat-treated parts were quenched in the critical range, resulting in an undesirable ferrite-martensite microstructure. Practically all of the carburized parts appeared to have been treated in molten cyanide

salts. Many of the carburized parts, such as wood screws and other non-moving parts, would appear to serve equally well without the added heat treatment.

The stock and forearm were examined by the Forest Products Laboratory of the United States Department of Agriculture, and found to be of plywood construction, made from beech veneer glued with phenolformaldehyde synthetic resin.

ECONOMIC CONSIDERATIONS

This model of the Mauser rifle has largely been made from conventional materials by older and well-accepted manufacturing methods. Significantly, the Germans have failed to take advantage of simplifying techniques necessary to successful mass production. No welded or brazed parts and only two stampings were used. The plywood stock, which is an adequate substitute for unavailable walnut, does not represent a shortening of the manufacturing process. Low-carbon steel forgings used for a number of parts, such as the trigger housing, are not generally considered more satisfactory in service than built-up parts, and they represent a considerable waste of steel, machine time, and man hours of labor.

DISCUSSION OF RESULTS

The Mauser rifle, as it was received, is shown in Figure 1, together with a photograph of the plywood stock which is one of the interesting parts of this model of the rifle. The parts of the disassembled rifle are shown in Figure 2. The plywood stock was examined by Mr. George M. Hunt, Acting Director of the Forest Products Laboratory, United States Department

of Agriculture, who made the following comments:

"The stock is made of rotary cut parall l laminated beech veneer approximately 1/20-inch thick. The sheets of veneer were glued together with a phenolformaldehyde synthetic resin adhesive. This glue was probably a liquid resin glue rather than a film resin of the Tego type.

"In shaping the stock the films of reddish glue between the laminations fan out to give the appearance of coniferous wood with annual rings distinguished by dense bands of Summer wood."

Type of Steel

All of the metal parts of the Mauser rifle were subjected to a sparking test. No indication of the use of alloy steel in the rifle was found. Representative parts were selected and analyzed chemically and spectroscopically with the results shown in Table 1. From this, it is concluded that only one part (a spring) was made from alloy steel. For this part a Si-Mn alloy spring steel was used.

Hardness and microscopic examinations were made upon the principal parts of the rifle. The results of these examinations are recorded in Table 2. The extensive use of heat treatment and numerous failures to attain the most desirable type of microstructure were the most important observations.

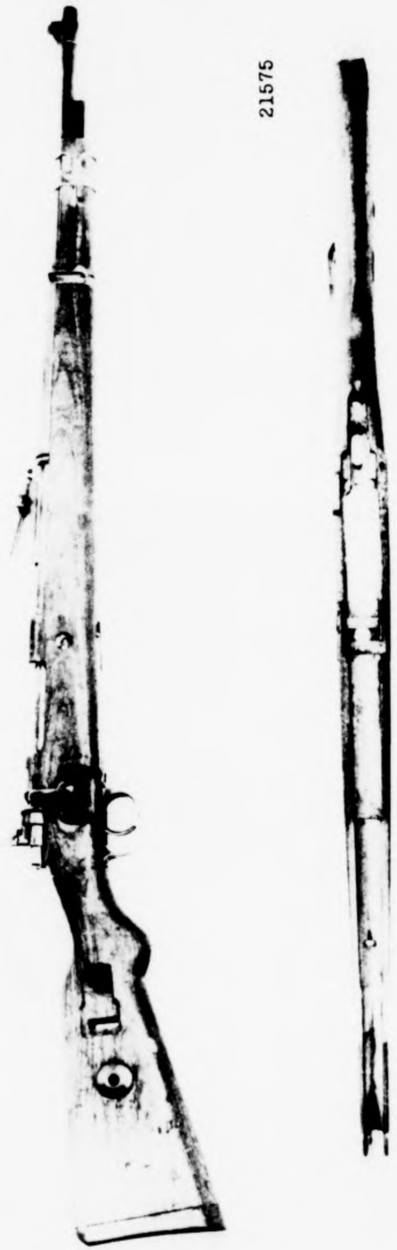

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Figure 1. German Mauser Rifle As-Received, Together With the Photograph of the Plywood Gun Stock.

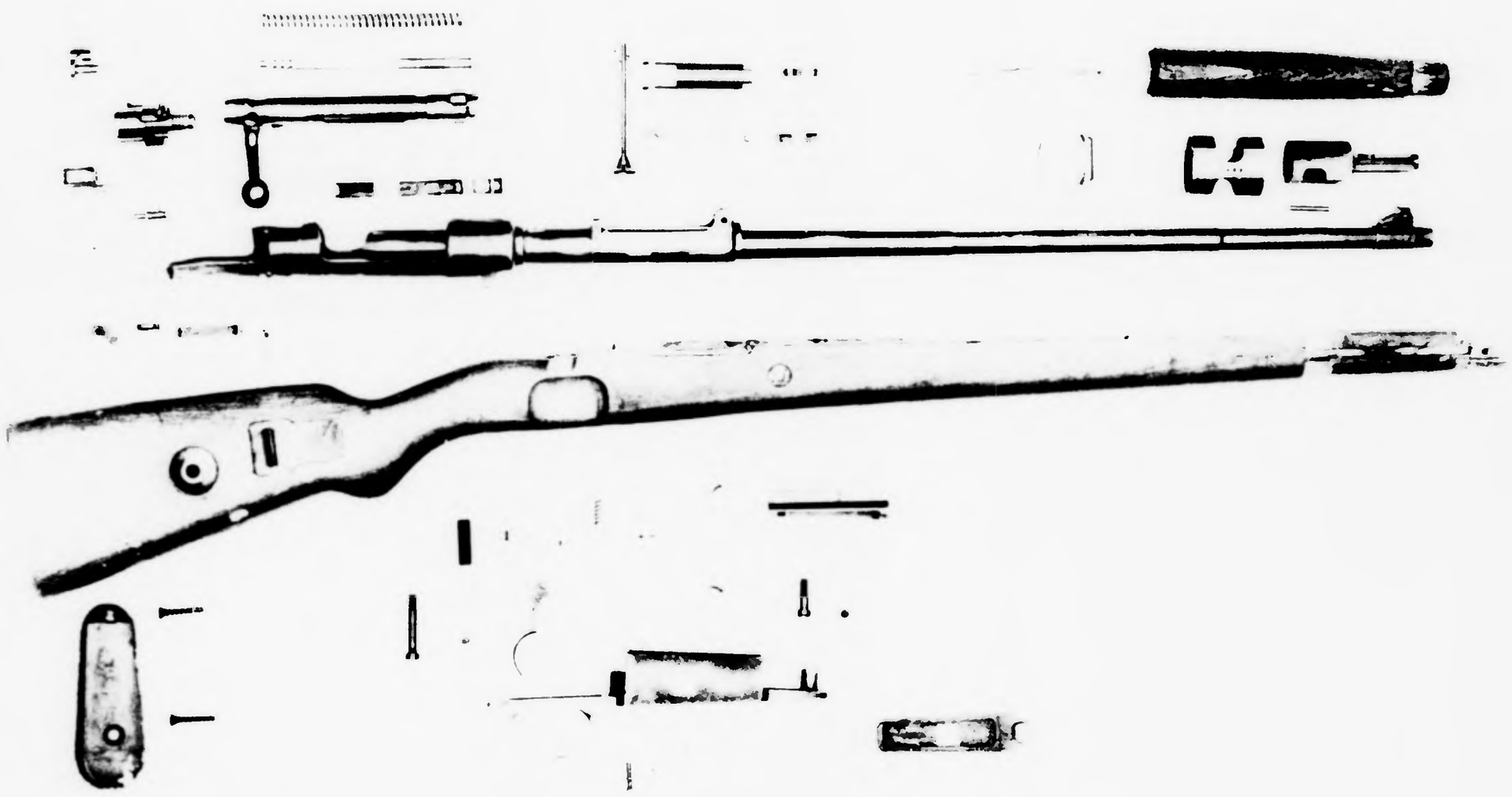

Figure 2. German Mauser Rifle Disassembled.

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TABLE 1. ANALYSES OF STEEL SAMPLES OF GERMAN MAUSER RIFLE

	Chemical and Spectrographic Analyses, %														
Sample	C*	Mn	P*	S*	Si	Ni	Cr	W	V	Mo	Cu	Sn	Al	Ti	Zr
Bolt	.46	.67	.019		.29	.06	.13	<.01	<.004	.007	.12	.012	<.007	<.008	<.02
Extractor	.69	.88	.018		1.40-1.60	.08	.15	<.01	<.004	.06	.16	.064	.028	<.008	<.02
Firing Pin	.66	.73	.030		.28	.07	.11	<.01	<.004	.009	.25	.009	.007	<.008	<.02
Firing Pin Spring		.13			.10	.09	<.03	<.01	<.004	.011	.30	.055	.005		
Rear Guard Screw	**	.40			.20	.12	.08	<.01	<.004	.018	.13	.014	<.005	<.008	<.02
Trigger	**	.30	.010		.24	.05	.03	<.01	<.004	<.005	<.04	.003	<.005	<.008	<.02
Sear	.62	.71	.010		.35	.11	.14	<.01	.012	.027	.16	.006	<.005	<.008	<.02
Rifle Barrel	.75	.54	.010	.016	.34	.11	.07	<.01	<.004	.011	.15	.012	<.005	<.008	<.02
Breech	.34	.56	.010	.045	.27	.10	.25	<.01	<.004	.12	.12	.015	<.005	<.008	<.02
Trigger Housing	.16		.012	.033											
Butt Plate	**		.011	.053											

* Analyzed chemically.
** Carburized parts.

TABLE 2. GERMAN MAUSER RIFLE PART DATA

Part No.	Name	Rockwell Hardness Number	Vickers Hardness Number	Remarks	Microstructure
1	Bolt	C17-C55	606	Forged, hardened differentially.	Coarse-grained martensite in hardened area. Pearlite and ferrite in as-forged area.
2	Extractor	C50	513	Bar stock.	Coarse-grained martensite.
3	Extractor Collar	C52	540	Bar stock, machined.	Martensite and some ferrite.
4	Firing Pin	C46, C16, C10	458	Tempered differentially, bar stock.	Thin, high-carbon case .0004", free carbide; tempered martensite in core.
5	Firing Pin Spring	C53	566	Wire.	High-carbon wire, structure distorted by cold drawing.
6	Safety Thumb Piece	Case- 724 Core- 473		Bar stock, cyanide case .01".	Fine martensite, no free carbides in case. Low-carbon martensite in core.
7	Firing Pin Cap	C56	617	Bar stock, cyanide case .01".	Coarse martensite case and core, no free carbides.
8	Thumb Piece Locking Pin	C43	424	Bar stock.	Uniform tempered martensite.
9	Thumb Piece Locking Spring			Wire.	
10	Safety Lock	C42	413	Bar stock, thin cyanide case .001".	Case, fine tempered martensite; core, tempered martensite and free ferrite.

Table 2. German Mauser Rifle Part Data (Continued)

Part No.	Name	Rockwell Hardness Number	Vickers Hardness Number	Remarks	Microstructure
11	Bayonet Chock	B84		Forged, thin cyanide case .002".	Fine martensite, no carbides in case. Core - 80% ferrite, 20% psuedo martensite.
12	Bayonet Chock Guard	B46	144	Low-carbon, rim steel tube.	Ferrite rim; few spheroidized carbides and ferrite in center.
13	Bayonet Chock Pin	B86		Cold-drawn wire.	Elongated crystals of pearlite and ferrite.
14	Forearm			Plywood.	
15	Hand Guard Clasp	B57	160	Low-carbon forged steel.	Pearlite and ferrite.
16	Hand Guard Clasp Spring	C50	513	Bar stock.	
17	Stock			Plywood.	
18	Trigger Guard	B70		Low-carbon forged steel.	Pearlite and ferrite.
19	Magazine Floor Plate	C41 & B64	403-160	Differentially hardened bar stock.	Banded structure changing from tempered martensite to pearlite and ferrite.
20	Magazine Spring			High-carbon flat strip.	
21	Follower	Case- 707 Core- 185		Bar stock, cyanide case ±.004".	Case, coarse martensite, no carbides Core, free ferrite and psuedo martensite.
22	Front Guard Screw	C13		Bar stock, cyanide case .01".	Case, martensite, no carbides. Core, quenched in critical martensite and ferrite.

Table 2. German Mauser Rifle Part Data (Continued)

Part No.	Name	Rockwell Hardness Number	Vickers Hardness Number	Remarks	Microstructure
23	Front Guard Lock Screw	Core- B96		Bar stock, cyanide case ± .002".	Case, uniform martensite; core, martensite and ferrite.
24	Rear Guard Screw	C28	285	Bar stock, cyanide case ±.005".	Case, uniform martensite, no carbides; core, coarse martensite.
25	Rear Guard Lock Screw	Core- B96		Bar stock, cyanide case ±.002".	Case, uniform martensite; core, martensite and ferrite.
26	Guard Screw Bushing			(File soft), cold-drawn tube.	Pure iron, ferrite and some oxide inclusions.
27	Trigger	Core- C14 Case- C42	204 423	Bar stock, carburized case ±.125".	Case, tempered martensite, no carbides; core, banded ferrite stringers and tempered martensite.
28	Trigger Sear	C43	424	Bar stock.	Uniform sorbite with a few small carbides.
29	Trigger Sear Spring			Wire.	
30	Trigger Sear Pin		578	Wire.	Fine-grained tempered martensite.
31	Trigger Pin			Wire.	
32	Floor-Plate Catch	C37	363	Bar stock, cyanide case .01".	Case and core, uniform martensite.
33	Floor-Plate Catch Spring			Wire.	
34	Floor-Plate Catch Pin			Wire.	
35	Butt Plate	C42	413	Sheet-steel stamping, cyanide case ±.002".	Case, uniform martensite; core, martensite and troostite.

Table 2. German Mauser Rifle Part Data (Continued)

Part No.	Name	Rockwell Hardness Number	Vickers Hardness Number	Remarks	Microstructure
36	Butt Plate Screw (Upper)	Core- C14	Core-173 Case-483	Cold headed, machine-cut threads, cyanide case ±.005".	Case, martensite; core, martensite and ferrite.
37	Butt Plate Screw (Lower)	Core- C14	Core-173 Case-483	Cold headed, machine-cut threads, cyanide case ±.005".	Case, martensite; core, martensite and ferrite.
38	Barrel	C19-C22	236-241	Bar stock, not hammer forged.	Uniform, sorbitic structure.
38A	Breech	C17-C30	236-301	Forged.	Tempered martensite and large ferrite ghost bands.
38B	Front Sight Base		166	Bar stock.	Ferrite and pearlite, mild carbon steel.
39	Cut-off	C49	498	Bar stock, transverse fiber.	Uniform sorbite from tempering of hardened steel part.
40	Cut-off Spring	C45	446	Bar stock.	
41	Cut-off Screw		Core-160	Bar stock, cyanide case .001".	Case, tempered martensite; core, ferrite with islands of psuedo martensite.
42	Ejector	C51	528-592	Stamped from high-carbon sheet, transverse fibers.	Uniform tempered martensite.
43	Ejector Spring	C48	478	Bar stock.	
44	Sight Leaf	C42	413	Bar stock.	Sorbitic structure from tempering.
45	Sight Base	C46-C53	458-562	Bar stock, cyanide case ±.01".	Case, coarse martensite, no carbides; core, course martensite and islands of ferrite.

Table 2. German Mauser Rifle Part Data (Concluded)

Part No.	Name	Rockwell Hardness Number	Vickers Hardness Number	Remarks	Microstructure
46	Sight Spring	C52	545	High-carbon strip.	
47	Sight Screw		Core-147	Bar stock, cyanide case .001".	Case, martensite, very sharp boundary with core; core, ferrite with islands of martensite.
48	Sight Slide	C39	383	Bar stock.	Fine-grained tempered martensite.
49	Sight Slide Cap	C41	403	Bar stock.	Tempered martensite or sorbite.
50	Sight Slide Spring			Wire.	
51	Sight Leaf Pin			Wire.	

LHG:ASH:JCD:AEW:JRC/ic
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